**Socioeconomic position and oral health in Chinese older adults: a life course approach**

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**Abstract**:

**Objectives** We investigated associations between socioeconomic position (SEP) across childhood, adulthood, and older age, and number of teeth among Chinese older adults.

**Methods** Data came from 15,136 participants aged 65-105 years in the Chinese Longitudinal Healthy Longevity Survey (2018 wave). The outcome was number of teeth. Pathways and sensitive period models were tested simultaneously using structural equation modelling (SEM). Ordinal logistic regression assessed the accumulation of risk and social mobility models. Differences were examined across four birth cohorts.

**Results** Adult and older age SEP had direct effects on number of teeth in older age (adulthood: $\beta_{direct}$=0.182, p<0.001; older age: $\beta_{direct}$=0.093, p=0.005), supporting the sensitive period model. Childhood SEP had an indirect effect on number of teeth ($\beta_{indirect}$=0.130, p<0.001) through adult and older age SEP, supporting the pathway / accumulation of risk and social mobility models. Effects of SEP on number of teeth were more pronounced in younger cohorts. Graded associations in the expected directions were found between the number of periods participants experienced disadvantaged SEP and number of teeth, as well as social mobility trajectories and number of teeth.

**Conclusion** Among Chinese older adults, the number of remaining teeth is subject to marked social inequalities. Our findings document the simultaneous applicability of life course models and a widening of oral health inequalities in China across generations. Interventions earlier in child and adult life are needed to address this problem and reduce oral health inequalities.

**Knowledge Transfer Statement** The findings of this study suggest marked socioeconomic inequalities in oral health among Chinese older adults. These inequalities are generated throughout the lifecourse and appear to have widened across cohorts. This study emphasises that interventions are needed to address the social determinants of oral health at all life stages.

MESH Keywords: Tooth Loss, Geriatric Dentistry, Social Inequalities, Epidemiology, Structural Equation Modelling, Life Course Perspective

## Introduction

Good oral health is an important part of healthy ageing. Oral conditions are among the most prevalent causes of disability-adjusted life-years among older populations globally (Vos et al., 2020). Among adults aged 65-74 in China, the prevalence of edentulousness decreased from 6.8% in 2005 to 4.5% in 2015, but the prevalence of good periodontal status (defined according to the 2018 classification of periodontal disease) decreased from 14.1% to 9.3% (Chinese Stomatological Association, 2018). The increasing burden of oral diseases and other chronic conditions, coupled with China's fast ageing population, will put further strain on the nation's resources, while oral health inequalities are considerable and increasing (Zhang and Chen, 2019).

A life course perspective to oral conditions is appropriate, given they are chronic, highly prevalent, cumulative, and can be reliably measured (Nicolau et al., 2007, Heilmann et al., 2015). Life course conceptual models explain how exposures across the life span influence later-life morbidity (Ben-Shlomo and Kuh, 2002). The sensitive period model applies to exposures that have an effect (or stronger effect) on a disease outcome during a certain time window, irrespective of circumstances in other periods. The accumulation of risk model suggests that adverse exposures are accumulated incrementally over the lifespan. The pathway or chain of risk model indicates that earlier risk factors influence subsequent health outcomes indirectly via later risk factors. An alternative approach for conceptualising accumulation of risk, the social mobility model, considers how the lifetime movement of an individual within social hierarchies may affect later-life health (Hallqvist et al., 2004).

Oral health life course studies have mostly employed traditional regression analyses (Bernabé et al., 2011, Gulcan et al., 2015, Holst and Schuller, 2012, Han and Khang, 2017, Ramsay et al., 2018, Pearce et al., 2004, Lee, 2019, Zhang and Chen, 2019, Green and Popham, 2017), which are methodologically limited and may underestimate associations (Moosbrugger et al., 2009, De Stavola et al., 2015). Application of more advanced techniques, such as theory-driven structural equation modelling (SEM), can elucidate the pathways linking lifecourse SEP and oral health, while accounting for measurement error and intermediate confounders (Moosbrugger et al., 2009, Baker and Gibson, 2014, De Stavola et al., 2015). Only two studies have used SEM to decompose the direct and indirect effects of lifetime SEP on tooth loss in later life, suggesting that childhood SEP affects later-life tooth loss mainly indirectly via adult SEP (Celeste et al., 2020, Zhang et al., 2023).

Existing evidence on associations between lifecourse SEP and oral health comes mainly from high-income countries (HICs), while the topic is underinvestigated in low- and middle-income countries (LMICs) including China (Zhang and Chen, 2019). Social stratification and social mobility in China differ considerably from those in HICs, partly because China's political and economic system underwent extensive historical changes (Bian, 2002). Testing the applicability of life course theories to populations in diverse cultural and socioeconomic settings could enrich the broader understanding of health inequalities and inform interventions that can be adapted to various contexts. Another under researched area is the existence of cohort effects (generational differences) in the association between SEP and later-life oral health in China, which underwent significant historical changes that were experienced differently across birth cohorts (Ahacic et al., 2007). A recent study examined pathways from childhood SEP to edentulousness among adults in the China Health and Retirement Longitudinal Study but did neither include old age SEP nor investigate cohort effects (Zhang et al., 2023). Moreover, no research has examined oral health inequalities among people aged 80 years and over in China. Given the global trend of an aging population, significant gaps in the evidence exist that require addressing. The current study aimed to test the applicability of different life course models to number of teeth in a nationally representative sample of older Chinese aged 65-105 years. We also examined whether associations varied between four birth cohorts. We hypothesised that childhood and adult SEP would affect number of teeth directly and also indirectly via older age SEP, and that those who experienced more socio-economic disadvantage over the lifecourse would have fewer teeth in old age. In addition, we anticipated cohort effects with number of teeth being more socially patterned among younger cohorts.

## Materials and Methods

*Study population*

We used cross-sectional data from the latest wave (2018) of the Chinese Longitudinal Healthy Longevity Survey (CLHLS) (Center for Healthy and Development, 2020). Participants aged 65 years and over were randomly selected from 631 counties and cities in 23 out of 31 provinces, representing approximately 85% of the Chinese population (Zeng et al., 2008). The CLHLS adopted a multi-stage disproportionate and targeted random sampling method

(Appendix 1). Centenarians and nonagenarians were over-sampled. Those older than 105 years were excluded due to lack of sampling weights. Data on socio-demographic characteristics, life satisfaction and personality, cognitive ability, health behaviours, ability to perform daily activities, and physical health were collected through face-to-face interviews and physical examinations in 2018-2019. Further details on sampling design and data quality can be found elsewhere (Zeng et al., 2008).

*Socioeconomic position (SEP)*

SEP, the exposure, was measured at three life stages (childhood, adulthood, and older age). Childhood SEP was assessed retrospectively via father's education (0; ≥1 year) and main occupation (manual or unemployed; non-manual). Adult SEP was retrospectively measured through participants' education (0; 1-6; ≥7 years) and main occupation before the age of 60 years (manual or unemployed; non-manual). Older age SEP was composed of self-rated economic status at the time of the survey and annual household income in the previous year (2017). Self-rated economic status was based on the question: "How would you rate your economic status compared with neighbours?". Answers were categorised as "poor or very poor", "fair", and "good or very good". The CLHLS did not code the exact value of income above 100,000 Chinese yuan. Therefore, annual household income tertiles were used: "low, <¥10,000 (equivalent to [i] <$1,476)", "medium, ¥10,000-50,000 ($1,4761-7,396)", and "high, >¥50,000 (>$7,396)".

Cumulative disadvantage was measured by summing the number of time periods participants experienced disadvantaged SEP[ii], resulting in four categories: disadvantaged SEP in "zero

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[i] Average exchange rate US Dollar ($) to China Renminbi (¥) in 2017 was 6.76.

[ii] Childhood disadvantaged SEP score = 1 (SEP disadvantage/low SEP in childhood) if father's educational attainment was no schooling AND father's occupation in childhood was manual or unemployed; Childhood disadvantaged SEP score = 0 (no SEP disadvantage/high SEP in childhood) if father had formal education OR father's occupation was non-manual, OR both.

Adulthood disadvantaged SEP score = 1 (SEP disadvantage/low SEP in adulthood) if participant's educational attainment was no schooling AND participant's occupation was manual or unemployed; Adulthood disadvantaged SEP score = 0 (no SEP/high SEP disadvantage in adulthood) if participant had formal education OR own occupation was non-manual, OR both.

Older age disadvantaged SEP score = 1 (SEP disadvantage/low SEP in older age) if self-rated economic status was poor AND low annual household income. Older age disadvantaged SEP score = 0 (no SEP disadvantage/high SEP in older age) if self-rated economic status was average or good OR annual household income was medium or high, OR both.

periods", "one period", "two periods", and "three periods". Based on this, a social mobility variable was created, with five possible trajectories: "stable advantaged (high – high – high)", "upward (low – high – high or low – low - high)", "fluctuating (low – high – low or high – low – high)", "downward (high – high – low or high – low -low)", and "stable disadvantaged (low – low – low)".

*Number of teeth in older age (outcome)*

Tooth loss reflects the accumulation of oral disease over the lifecourse. Previous validation studies of oral health measures supported the validity of using self-reports to measure the number of natural teeth (Shen et al., 2013, Matsui et al., 2017). Participants were asked to count the number of natural teeth present (including fixed prosthetics) at the time of the 2018 survey, assisted by medical personnel (Center for Healthy and Development, 2020). Number of teeth ranged from 0 to 32 and was categorised into four ordered groups (Appendix 2) for all analyses: 0 teeth (edentulousness), 1-9 teeth, 10-19 teeth, 20-32 teeth (functional dentition).

*Covariates*

Covariates included age, sex, urban/rural residence, and region. Regions were categorised according to the National Bureau of Statistics of China: east China. central China, and west China. Urban/rural residence and region were included because of their considerable variation in economic development and health care accessibility.

*Statistical analysis*

The percentage of incomplete data was 16%. Multiple imputation of missing data on all exposures and covariates was carried out using the chained equation approach in Stata/SE 17. Appendix 3 presents the diagnostic plots of the distribution of the SEP variables for all thirty-five imputations, showing that the values vary randomly. The results obtained from complete case analyses and analyses using multiple imputation were similar (Appendix 3).

Chi-squared tests estimated the crude associations between each independent variable and number of teeth (summarised with proportion estimate and standard error, S.E.). Sampling weights were used to account for the survey design and ensure comparability of the sample with the standard population on age, rural/urban residence, and sex distribution.

Multicollinearity diagnostics indicated non-collinearity between the SEP measures (Appendix 3).

To test the four socioeconomic life course theoretical models, SEM was carried out using Mplus 8.4. SEM can work with observed and latent variables, model both direct and indirect effects, and take measurement errors into account (Weston and Gore Jr, 2006). Figure 1 shows the analytical model. Childhood SEP, a latent variable evaluated by fathers' education and occupation, was modelled as having a direct effect on number of teeth through path *a*, and indirect effects through paths *dec* and *db*. Adult SEP, measured by participants' education and main occupation, was modelled to have a direct effect (path *b*) and indirect effect (path *ec*). Older age SEP, consisting of self-rated economic status and annual household income, was modelled as having only a direct effect through path *c*. Multiple group analysis was performed to examine whether associations varied between the four birth cohorts. The following indices were considered as indicators of good model fit: a) Root Mean Square Error of Approximation (RMSEA) $\leq$ 0.06; b) Standardized Root Mean Squared Residual (SRMR) $\leq$ 0.08; and c) Comparative Fit Index and the Tucker Lewis Index (CFI/TLI) $\geq$ 0.95 (Hu and Bentler, 1999). Weighted least squares mean and variance (WLSMV) estimation was used to fit categorical data. Thirty-five imputed datasets were imported from Stata/SE 16 to address WLSMV's limitations of handling missing data. Theta parameterization was used, as recommended when estimating residuals for polytomous outcomes and multiple group analysis (Muthén and Asparouhov, 2002). Bootstrap assessment with 500 repetitions was conducted to assess estimation uncertainty. All models adjusted for demographic characteristics.

To explore the social mobility model, ordinal logistic regression with partial proportional odds (PPO) models were analysed. First, the associations between social mobility trajectories and number of teeth were examined, adjusting for demographic characteristics. Second, subgroup analyses stratified by birth cohort were conducted. Odds Ratios (OR) were reported with their 95% Confidence Interval (CI). Accumulative risk models could also be tested using traditional regression models. We conducted a sensitivity analysis estimating a fully adjusted regression model using cumulative disadvantage as the exposure.

**Results**

Table 1 presents the distribution of number of teeth by SEP and demographic characteristics of 15,136 participants aged 65-105 years. Overall, 15.3% of participants were edentulous, 18.7% had 1-9 teeth, 19.7% had 10-19 teeth, and 46.3% reported having a functional dentition (≥20 teeth). Women, older cohorts, those living in rural areas, and those from the western region of China had higher prevalence of edentulousness and lower prevalence of functional dentition. These were also socially patterned, with edentulousness most common and functional dentition least common among participants with lower SEP, and those who experienced more periods of socioeconomic disadvantage in their life.

Table 2 shows standardised direct, indirect, and total effects of SEP at three life stages on number of teeth in older age. For the overall sample (not stratified by cohort), factor loadings for all latent variables were significant and substantially high (all βs>0.50), indicating that the constructed latent variables successfully summarised the information contained in the observed variables. The goodness-of-fit statistics indicated that the hypothesised SEP model was an excellent fit to the data. Adult and older age SEP had direct effects on number of teeth, suggesting that higher SEP in these two sensitive periods was associated with having more teeth in older age (adulthood: $\beta_{direct}=0.182$, $p<0.001$; older age: $\beta_{direct}=0.093$, $p=0.005$). However, the childhood SEP direct path estimate was negative and not significant ($\beta_{direct}= -0.057$, $p=0.145$). Childhood SEP had an indirect effect ($\beta_{indirect}=0.130$, $p<0.001$) on number of teeth via adult SEP and older age SEP, indicating chain of risks. Adult SEP and older age SEP together accounted for 70.0% of the total effect between SEP across the life course and number of teeth, while older age SEP alone accounted for 24.0% of the total effect of SEP in adulthood on number of teeth.

The associations between SEP and number of teeth varied between birth cohorts (Table 2). The multiple group analysis fitted the data well. All factor loadings for the latent SEP constructs in three periods were significant across the four cohorts. Substantial direct effects of adult SEP on number of teeth in the three younger cohorts (those born in 1941 or later, the 1931-1940 cohort, and the 1921-1930 cohort) suggested that adulthood was a sensitive period for tooth retention. A direct effect of older age SEP on number of teeth was only observed in the youngest cohort, demonstrating that older age was a sensitive period for those born in 1941 or later. Also, indirect effects of childhood SEP were found in the three younger cohorts pointing towards chains of risks.

Due to violation of the proportional odds assumption, a partial proportional odds (PPO) model was used to obtain estimates for each dichotomisation of the outcome. Table 3 revealed that the odds of having a functional dentition for those who experienced upward social mobility, fluctuating social mobility, and stable low SEP between childhood and older age were 17% (OR=0.83, 95% CI=0.72-0.95), 42% (OR=0.58, 95% CI=0.44-0.76), and 48% (OR=0.52, 95% CI=0.35-0.78) lower than for those who experienced a stable high SEP, respectively. In PO analyses stratified by birth cohort, graded patterns were only observed in the three younger cohorts (Figure 2).

Sensitivity analyses for the accumulation of risks model suggested a clear negative social gradient (Appendix 4). Overall, a higher lifetime exposure to disadvantaged SEP was associated with reporting fewer teeth in old age. When stratified by birth cohorts, a greater life course exposure to disadvantaged SEP was associated with having fewer teeth in older age among the three younger cohorts only.

## Discussion

Using the Chinese older adult population to investigate associations between life course SEP and number of teeth, this study showed that the number of remaining teeth is subject to marked social inequalities. Our findings document the simultaneous applicability of life course models and a widening of oral health inequalities in China across generations.

Adulthood and older age were sensitive periods for number of teeth in later life, during which Chinese older adults were particularly sensitive to socioeconomic disadvantage (Green and Popham, 2017). The particularly strong influence of later SEP on oral health might be due to its immediate and stronger influence on health behaviours and access to care, making it more impactful in shaping health outcomes in older age (Ben-Shlomo and Kuh, 2002). We also observed no direct but a strong indirect effect of childhood SEP on number of teeth in later life, in line with a study on edentulousness among Chinese adults aged 45 years and over (Zhang et al., 2023) and a relevant Swedish longitudinal study (Celeste et al., 2020). These findings support the accumulation of risk model, suggesting that the effect of childhood SEP on oral health is long-lasting and cumulative, while also reflecting intergenerational (childhood to adulthood) and intra-individual (adulthood to older age) social mobility, providing support for the social mobility model. However, other studies conducted in HICs found that childhood is a sensitive period for oral health (Bernabé et al., 2011, Han and Khang, 2017, Lee, 2019, Celeste et al., 2020). The different findings in HICs and China might be explained by China's unique social and economic historical transformation. All participants in the present study were born before 1954 and spent their childhood before the economic reform in 1978, when China was mostly a pre-industrial society with low literacy rates and a predominantly rural population. Access to dental services was very limited, as China had one of the lowest dentist-to-population ratios in the world (Schattner and Tsao, 1981). Government funding and policies to improve oral health were lacking, with the focus being primarily on communicable diseases (Zhou et al., 2013). However, those from higher SEP households would have been more likely to access expensive sugary products, tobacco, and alcohol in their youth (Chen et al., 2010). In this context, the socioeconomic advantage that granted dental services access may have been offset by higher sugar intake and other risk factors associated with more affluent lifestyles. These mutual protective and harmful effects might explain why childhood SEP had no direct effects on number of teeth in our sample.

We observed a social gradient in relation to the accumulation of socioeconomic disadvantage and number of teeth, corresponding to the accumulative risk model and corroborating studies conducted in HICs (Bernabé et al., 2011, Han and Khang, 2017, Ramsay et al., 2018, Lee, 2019, Celeste et al., 2020). Consistent with previous work testing the social mobility model (Han and Khang, 2017, Ramsay et al., 2018, Lee, 2019, Celeste et al., 2022, Astrom et al., 2015, Pearce et al., 2009), having a stable advantaged SEP across the life course was most beneficial for retaining more teeth in later life. However, differences between the stable advantaged and upwardly mobile groups were larger here than in other studies (Han and Khang, 2017, Ramsay et al., 2018, Lee, 2019). This might be explained by the strong effects of later SEP observed in our study, implying that upward mobility helped to compensate for early-life disadvantage. Meanwhile, the larger effect of fluctuating mobility (that includes both upward and downward mobility) could be explained by the direct effects of later SEP, as the effect of childhood SEP passes through a chain of SEP in adulthood and older age.

The multiple group analysis documented cohort effects, with adulthood identified as a sensitive period for number of teeth among the three younger cohorts, and older age identified as a sensitive period among the youngest group (born in 1941 or later). The lack of associations between SEP across the life course and number of teeth among the oldest cohort may reflect the low priority of dental care and high prevalence of periodontal diseases among all SEP groups in China before 1980, when this cohort entered old age (Schattner and Tsao, 1981). Throughout older adults' life in 20th century China, the participants and their parents were exposed to dramatic social and economic changes including wars, famine, revolutions, education reforms, industrialisation, and a massive increase in incomes. Therefore, the findings might reflect the remarkable social and economic developments in China over the past four decades that have contributed to health improvement, while social inequalities in health have also increased (Kendig et al., 2017). Additionally, effects of cumulative disadvantage and social mobility were found among the three younger cohorts, due to higher social inequalities among these cohorts.

A particular strength of this study is the examination of four life course models in relation to oral health among older adults in China. Identifying sensitive periods, exploring the accumulation of risks and pathways throughout the life course, and understanding the pattern of oral health inequalities can help guide interventions conducive to healthy longevity and oral health improvement in China. Additionally, CLHLS has a high response rate and a large sample of the oldest-old, while survey weights and multiple imputation reduced bias and improved generalisability. To assess older age SEP, latent variables were constructed to capture both subjective socioeconomic status (SSS) and objective annual household income. Subjective measures are considered to reflect not only people's current objective social circumstances, but also their past socioeconomic position (Singh-Manoux et al., 2003), and are widely used as SEP indicators in studies conducted in China (Wong et al., 2008).

Our study has some limitations. First, childhood and adult SEP were captured retrospectively and therefore are subject to recall bias. However, studies examining the validity of long-term recall data have demonstrated that individuals can report education and occupation and childhood adversities with reliability and accuracy (Hout and Hastings, 2016). Some important SEP measures (e.g., household income in childhood and adulthood) were not available and could not be included in the analysis, while education and social class had to be dichotomised.

To partly address these concerns, latent variables were constructed by including two SEP variables at each life stage. Second, the CLHLS does not collect information on oral health at earlier life stages, and it is possible that some tooth loss might precede adult and older age SEP. Finally, downward social mobility was rare (n=86 for the overall sample, n=5 for the oldest cohort), limiting statistical power to detect differences with this group.

Our findings have implications for potential interventions to promote good oral health. Given the pivotal role of adult SEP, interventions to reduce social inequalities, such as increasing access to education, reducing unemployment, and ensuring good physical and psychosocial working conditions for both manual and non-manual workers, can be relevant in this context (Kaikkonen et al., 2009). Meanwhile, social and welfare support to families with children, such as the provision of parental education and universal high-quality nursery/school education, might break the transmission and accumulation of social disadvantage, improve health, and reduce social inequalities (Raudenbush and Eschmann, 2015). Oral health inequalities have widened across generations in China, underscoring the urgency for appropriate interventions.

In conclusion, this study provides new important evidence for the influence of SEP across different life stages on oral health among the older Chinese population, highlighting also generational differences. Future research should examine the mechanisms through which oral health inequalities in China are created and develop strategies and interventions to effectively address them.

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**Contributors**

J. Hong contributed to conception, design, data acquisition and interpretation, performed all statistical analysis, drafted and critically revised the manuscript. R.G. Watt, G. Tsakos, and A. Heilmann contributed to conception, design, critically revised the manuscript, and supervised all aspects. All authors gave their final approval and agree to be accountable for all aspects of the work.

**Declaration of Conflicting Interests**

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Figure Legends:

*Figure 1 Analytical model for SEM analysis on the association between SEP and number of teeth*

*Figure 2 Adjusted associations between social mobility and number of teeth by birth cohort (n=15,136)*

***p<0.001; **p<0.01; *p<0.05. Analysis of imputed dataset. PO Models, all p-values > 0.01 in Brant's tests. Demographic characteristics were adjusted. Coefficients (βs) are reported in the social mobility model because one estimate of the oldest cohort is relatively large comparing with other estimates. The reference group is stable high SEP.

*Table 1 Descriptive statistics for people aged 65 years to 105 years in 2018 by number of teeth (n=15,136).*

| | Unweighted n | Column % (S.E.)^ | Number of teeth Row % (S.E)^ | | | | P value |
|---|---|---|---|---|---|---|---|
| | | | 0 | 1-9 | 10-19 | 20-32 | |
| | | | 15.3 (0.4) | 18.7 (0.5) | 19.7 (0.5) | 46.3 (0.7) | |
| **Demographic characteristics** | | | | | | | |
| *Sex* | | | | | | | |
| Male | 6,659 | 47.7 (0.7) | 13.8 (0.6) | 17.3 (0.7) | 19.9 (0.7) | 49.0 (0.9) | <0.001 |
| Female | 8,477 | 52.3 (0.7) | 16.8 (0.6) | 19.9 (0.7) | 19.4 (0.7) | 43.9 (0.9) | |
| *Birth year* | | | | | | | |
| 1941 or later | 4,289 | 74.1 (0.4) | 10.7 (0.5) | 14.9 (0.6) | 19.8 (0.7) | 54.6 (0.8) | <0.001 |
| 1931-1940 | 4,069 | 21.7 (0.4) | 25.9 (0.7) | 28.5 (0.7) | 20.5 (0.7) | 25.1 (0.7) | |
| 1921-1930 | 3,779 | 4.1 (0.1) | 41.4 (1.0) | 33.4 (1.0) | 14.1 (0.8) | 11.2 (0.7) | |
| 1920 or earlier | 2,999 | 0.2 (0.0) | 57.3 (1.8) | 30.1 (1.7) | 7.0 (0.9) | 5.6 (0.9) | |
| *Residential place* | | | | | | | |
| Rural | 6,721 | 49.5 (0.7) | 17.0 (0.6) | 19.0 (0.7) | 19.9 (0.8) | 44.1 (1.0) | <0.001 |
| Urban | 8,415 | 50.5 (0.7) | 13.7 (0.5) | 18.3 (0.6) | 19.5 (0.7) | 48.5 (0.9) | |
| *Region* | | | | | | | |
| Eastern | 7,569 | 50.0 (0.6) | 16.1 (0.6) | 18.0 (0.6) | 20.7 (0.7) | 45.1 (0.9) | <0.001 |
| Central | 3,851 | 26.1 (0.6) | 12.8 (0.7) | 18.3 (0.9) | 17.3 (1.0) | 51.5 (1.3) | |
| Western | 3,716 | 23.8 (0.6) | 16.4 (0.9) | 20.3 (1.0) | 20.1 (1.1) | 43.1 (1.4) | |
| **Childhood SEP** | | | | | | | |
| *Father's education* | | | | | | | |
| 0 years | 11,611 | 75.4 (0.6) | 16.6 (0.5) | 19.4 (0.5) | 19.6 (0.6) | 44.5 (0.8) | <0.001 |
| ≥ 1 year | 2,617 | 24.6 (0.6) | 11.5 (0.7) | 16.5 (0.9) | 20.0 (1.0) | 52.0 (1.3) | |
| *Father's occupation in childhood* | | | | | | | |
| Manual or unemployed | 14,237 | 95.0 (0.3) | 15.6 (0.4) | 18.6 (0.5) | 19.7 (0.5) | 46.0 (0.7) | 0.049 |
| Non-manual | 567 | 5.0 (0.3) | 10.2 (1.5) | 19.3 (2.3) | 18.5 (2.3) | 52.0 (3.0) | |
| **Adult SEP** | | | | | | | |
| *Own education* | | | | | | | |
| 0 years | 7,568 | 30.3 (0.6) | 21.0 (0.8) | 25.0 (0.9) | 18.9 (0.9) | 35.1 (1.1) | <0.001 |
| 1-6 years | 4,875 | 41.5 (0.7) | 15.7 (0.7) | 18.6 (0.8) | 20.0 (0.8) | 45.8 (1.0) | |
| ≥ 7 years | 2,705 | 28.2 (0.6) | 8.7 (0.6) | 12.0 (0.8) | 20.1 (1.0) | 59.2 (1.2) | |
| *Main occupation* | | | | | | | |
| Manual or unemployed | 13,597 | 89.1 (0.4) | 16.2 (0.4) | 19.3 (0.5) | 19.7 (0.5) | 44.8 (0.7) | <0.001 |
| Non-manual | 1,542 | 10.9 (0.4) | 8.5 (0.9) | 13.2 (1.2) | 19.6 (1.5) | 58.7 (1.8) | |
| **Older age SEP** | | | | | | | |
| *Annual household income* | | | | | | | |
| Low, <¥10,000 | 4,632 | 34.1 (0.6) | 18.1 (0.8) | 20.8 (0.8) | 19.6 (0.9) | 41.5 (1.1) | 0.001 |
| Medium, ¥10,000-49,999 | 4,709 | 34.7 (0.7) | 15.7 (0.7) | 19.0 (0.8) | 19.7 (0.9) | 45.6 (1.2) | |
| High ≥¥50,000 | 4,484 | 31.1 (0.6) | 11.9 (0.7) | 15.9 (0.8) | 19.8 (0.9) | 52.4 (1.2) | |
| *Self-rated economic status* | | | | | | | |
| Poor | 1,614 | 10.5 (0.4) | 18.4 (1.4) | 21.1 (1.5) | 22.4 (1.7) | 38.1 (2.0) | <0.001 |
| Fair | 10,440 | 70.9 (0.6) | 15.2 (0.5) | 19.3 (0.6) | 19.4 (0.6) | 46.1 (0.8) | |
| Good | 2,912 | 18.6 (0.5) | 14.3 (0.9) | 14.7 (0.9) | 19.1 (1.1) | 51.8 (1.5) | |
| ***Disadvantaged SEP in*** | | | | | | | |
| 0 periods | 1,996 | 22.0 (0.6) | 10.2 (0.7) | 14.9 (1.0) | 20.3 (1.1) | 54.6 (1.4) | <0.001 |
| 1 period | 4,624 | 47.4 (0.7) | 14.5 (0.6) | 16.7 (0.7) | 19.4 (0.8) | 49.4 (1.0) | |
| 2 periods | 5,413 | 28.1 (0.6) | 20.0 (0.8) | 24.3 (0.9) | 19.5 (0.9) | 36.2 (1.2) | |
| 3 periods | 728 | 2.6 (0.2) | 24.6 (3.0) | 24.8 (2.9) | 21.2 (3.3) | 29.4 (3.9) | |
| ***Social mobility*** | | | | | | | |
| Stable advantage | 1,996 | 22.0 (0.6) | 10.2 (0.7) | 14.9 (1.0) | 20.3 (1.1) | 54.6 (1.4) | <0.001 |
| Upward | 9,143 | 69.0 (0.6) | 16.3 (0.5) | 19.2 (0.6) | 19.3 (0.6) | 45.2 (0.8) | |
| Fluctuating | 745 | 5.5 (0.3) | 19.9 (2.1) | 23.0 (2.2) | 20.6 (2.2) | 36.5 (2.8) | |
| Downward | 149 | 1.0 (0.1) | 13.3 (4.4) | 23.3 (5.1) | 25.9 (6.1) | 37.5 (6.8) | |
| Stable disadvantage | 728 | 2.6 (0.2) | 24.6 (3.0) | 24.8 (2.9) | 21.2 (3.3) | 29.4 (3.9) | |

^Weighted percentages of imputed data. P-value was calculated for each imputed dataset, the highest one is reported.

*Table 2 Standardised factor loadings for observed variables, and standardised coefficients for total, direct and indirect effects (β) of socio-economic position in childhood, adulthood, and older age on oral health (n=15,136)*

| | Standardized coefficients (β) | | | | |
|---|---|---|---|---|---|
| | | Born in | | | |
| | All | 1941 or later | 1931-1940 | 1921-1930 | 1920 or earlier |
| **Confirmatory factor analysis** | | | | | |
| Childhood SEP BY | | | | | |
| Father's education | 0.845*** | 0.832*** | 0.801*** | 0.801*** | 0.726*** |
| Father's main occupation | 0.806*** | 0.800*** | 0.831*** | 0.898*** | 0.964*** |
| Adult SEP BY | | | | | |
| Education | 0.897*** | 0.860*** | 0.851*** | 0.831*** | 0.883*** |
| Main occupation | 0.828*** | 0.875*** | 0.901*** | 0.979*** | 0.993*** |
| Older age SEP BY | | | | | |
| Self-rated economic status | 0.464*** | 0.441*** | 0.542*** | 0.562*** | 0.584*** |
| Household income | 0.807*** | 0.787*** | 0.823*** | 0.789*** | 0.762*** |
| **Path analysis** | | | | | |
| Direct effects | | | | | |
| ***a*** (childhood SEP on teeth #) | -0.057 | -0.052 | -0.114 | 0.018 | 0.298 |
| ***b*** (adult SEP on teeth #) | 0.182*** | 0.183** | 0.338*** | 0.234* | -0.309 |
| ***c*** (older age SEP on teeth #) | 0.093** | 0.100* | 0.040 | -0.055 | 0.139 |
| ***d*** (childhood SEP on adult SEP) | 0.540*** | 0.539*** | 0.565*** | 0.489*** | 0.732*** |
| ***e*** (adult SEP on older age SEP) | 0.628*** | 0.613*** | 0.678*** | 0.746*** | 0.637*** |
| Indirect effects | | | | | |
| Childhood SEP → teeth # (*db+dec*) | 0.130*** | 0.132*** | 0.207*** | 0.094* | -0.161 |
| Adult SEP → teeth # (ec) | 0.058** | 0.061* | 0.027 | -0.041 | 0.089 |
| Total effects (direct effects + indirect effects) | | | | | |
| Childhood SEP on teeth # | 0.073** | 0.079* | 0.093** | 0.112* | 0.137 |
| Adult SEP on teeth # | 0.241*** | 0.244*** | 0.366*** | 0.193* | -0.220 |
| Older age SEP on teeth # | 0.093** | 0.100* | 0.044 | -0.055 | 0.139 |
| Fit statistics | | | | | |
| $\chi 2$ | 469.68 | 667.73 | | | |
| Df | 29 | 116 | | | |
| RMSEA | 0.032 | 0.035 | | | |
| SRMR | 0.039 | 1.557 | | | |
| CFI | 0.962 | 0.971 | | | |
| TLI | 0.928 | 0.946 | | | |

***p<0.001; **p<0.01; *p<0.05. Demographic characteristics were adjusted and omitted in all models. Analysis of imputed dataset.

*Table 3 Association between social mobility trajectories and number of teeth (n=15,136)*

| | Social mobility model – Odds Ratio (95% Confidence Interval) | |
|---|---|---|
| | PO model[i] | PPO model[ii] |
| ***Childhood-adulthood-older age social mobility trajectory*** | | |
| Stable high | 1.00 (reference) | |
| Upward | 0.78 (0.69-0.88)*** | |
| Fluctuating | 0.56 (0.45-0.71)*** | |
| Downward | 0.65 (0.41-1.01) | |
| Stable low | 0.55 (0.41-0.74)*** | |
| (Edentate = 0) v.s. (1-9 teeth + 10-19 teeth + ≥20 teeth = 1) | | |
| Stable high | | 1.00 (reference) |
| Upward | | 0.75 (0.63-0.89)** |
| Fluctuating | | 0.58 (0.42-0.80)** |
| Downward | | 0.91 (0.41-2.00) |
| Stable low | | 0.60 (0.40-0.89)* |
| (Edentate + 1-9 teeth = 0) v.s. (10-19 teeth + ≥20 teeth = 1) | | |
| Stable high | | 1.00 (reference) |
| Upward | | 0.76 (0.65-0.87)*** |
| Fluctuating | | 0.55 (0.43-0.72)*** |
| Downward | | 0.69 (0.40-1.19) |
| Stable low | | 0.56 (0.40-0.78)** |
| (Edentate + 1-9 teeth + 10-19 teeth = 0) v.s. (≥20 teeth = 1) | | |
| Stable high | | 1.00 (reference) |
| Upward | | 0.83 (0.72-0.95)** |
| Fluctuating | | 0.58 (0.44-0.76)*** |
| Downward | | 0.56 (0.30-1.04) |
| Stable low | | 0.52 (0.35-0.78)** |

Estimates of covariates were omitted. Weighted percentages of imputed data. ***p<0.001; **p<0.01; *p<0.05.

[i] results of the proportional odds model (PO), holding the parallel-lines assumption.

[ii] results of the partial proportional odds model (PPO), which relax the assumption of proportional odds for social mobility trajectories (Brant's test: $\chi^2_{\text{social mobility trajectory}}$ =14.77, p<0.01) and assume proportional odds for covariates (age, sex, region, and rural/urban residence).

## References

Ahacic K, Parker MG, Thorslund, M. 2007. Aging in disguise: age, period and cohort effects in mobility and edentulousness over three decades. Eur J Ageing, 4, 83-91.

Astrom AN, Ekback G, Lie SA, Ordell S. 2015. Life-course social influences on tooth loss and oral attitudes among older people: evidence from a prospective cohort study. Eur J Oral Sci. 123(1): 30-8.

Baker SR, Gibson BG. Social oral epidemi (olog) 2y where next: one small step or one giant leap? 2014. Community Dent Oral Epidemiol. 42(6): 481-94.

Ben-Shlomo Y, Kuh D. 2002. A life course approach to chronic disease epidemiology: Conceptual models, empirical challenges and interdisciplinary perspectives. Oxford: Oxford University Press.

Bernabé E, Suominen AL, Nordblad A, Vehkalahti MM, Hausen H, Knuuttila M, Kivimäki M, Watt RG, Sheiham A, Tsakos G. 2011. Education level and oral health in Finnish adults: Evidence from different lifecourse models. J Clin Periodontol. 38(1):25-32.

Bian Y. 2002. Chinese social stratification and social mobility. Annu Rev Sociol. 28(1):91-116.

Celeste RK, Darin-Mattsson A, Lennartsson C, Listl S, Aurelio M. 2022. Social mobility and tooth loss: A systematic review and meta-analyses. J Dent Res. 101(2):143-150.

Celeste RK, Eyjólfsdóttir HS, Lennartsson C, Fritzell J. 2020. Socioeconomic life course models and oral health: A longitudinal analysis. J Dent Res. 99(3):257-263.

Center for Healthy Ageing Development S. 2020. The Chinese Longitudinal Healthy Longevity Survey (CLHLS)-longitudinal data (1998-2018). V2 ed. Beijing: Peking University Open Research Data Platform. [accessed 12 Jan 2021]. https://doi.org/10.18170/DVN/JD2PYJ

Chen F, Yang Y, Liu G. 2010. Social change and socioeconomic disparities in health over the life course in China: A cohort analysis. Am Sociol Rev. 75(1):126-150.

Chinese Stomatological Association. 2018. Fourth national oral health epidemiological survey report. Beijing: People's Medical Publishing House.

De Stavola BL, Daniel RM, Ploubidis GB, Micali N. 2015. Mediation analysis with intermediate confounding: Structural equation modeling viewed through the causal inference lens. Am J Epidemiol. 181(1):64-80.

Green MJ, Popham F. 2017. Life course models: Improving interpretation by consideration of total effects. Int J Epidemiol. 46(3):1057-1062.

Gulcan F, Ekback G, Ordell S, Lie SA, Astrom AN. 2015. Inequality in oral health related to early and later life social conditions: A study of elderly in Norway and Sweden. BMC Oral Health. 15:1-10.

Hallqvist J, Lynch J, Bartley M, Lang T, Blane D. 2004. Can we disentangle life course processes of accumulation, critical period and social mobility? An analysis of disadvantaged socio-economic positions and myocardial infarction in the Stockholm Heart Epidemiology Program. Soc Sci Med, 58, 1555-1562.

Han DH, Khang YH. 2017. Lifecourse socioeconomic position indicators and tooth loss in Korean adults. Community Dent Oral Epidemiol. 45(1): 74-83.

Heilmann A, Tsakos G, Watt R. 2015. Oral health over the life course. A life course perspective on health trajectories and transitions. Geneva: Spinger. pp. 39-60.

Holst D, Schuller AA. 2000. Oral health changes in an adult Norwegian population: A cohort analytical approach. Community Dent Oral Epidemiol. 28(2):102-111.

Hout M, Hastings OP. 2016. Reliability of the core items in the General Social Survey: estimates from the three-wave panels, 2006–2014. Sociol Sci. 3, 971-1002.

Hu LT, Bentler PM. 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Modeling. 6(1):1-55.

Kaikkonen R, Rahkonen O, Lallukka T, Lahelma E. 2009. Physical and psychosocial working conditions as explanations for occupational class inequalities in self-rated health. Eur J Public Health, 19(5), 458-463.

Kendig H, Gong CH, Yiengprugsawan V, Silverstein M, Nazroo J. 2017. Life course influences on later life health in China: Childhood health exposure and socioeconomic mediators during adulthood. SSM Popul Health. 3:795-802.

Lee H. 2019. A life course approach to total tooth loss: Testing the sensitive period, accumulation, and social mobility models in the health and retirement study. Community Dent Oral Epidemiol. 47(4):333-339.

Matsui D, Yamamoto T, Nishigaki M, Miyatani F, Watanabe I, Koyama T, Ozaki E, Kuriyama N, Kanamura N, Watanabe, Y. 2017. Validity of self-reported number of teeth and oral health variables. BMC Oral Health, 17, 1-8.

Moosbrugger H, Schermelleh-Engel K, Kelava A, Klein AG. 2009. Testing multiple nonlinear effects in structural equation modeling: A comparison of alternative estimation approaches. Structural Equation modeling in Educational Research: Concepts And Applications. Rotterdam: Sense Publishers. pp. 103-136.

Muthén B, Asparouhov T. 2002. Latent variable analysis with categorical outcomes: Multiple-group and growth modeling in mplus. Mplus web notes. 4(5):1-22.

Nicolau B, Thomson W, Steele J, Allison P. 2007. Life-course epidemiology: Concepts and theoretical models and its relevance to chronic oral conditions. Community Dent Oral Epidemiol. 35(4):241-249.

Pearce MS, Steele JG, Mason J, Walls AW, Parker L. 2004. Do circumstances in early life contribute to tooth retention in middle age? J Dent Res. 83(7):562-566.

Pearce MS, Thomson WM, Walls AWG, Steele JG. 2009. Lifecourse socio-economic mobility and oral health in middle age. J Dent Res. 88(10):938-941.

Ramsay SE, Papachristou E, Watt RG, Lennon LT, Papacosta AO, Whincup PH, Wannamethee SG. 2018. Socioeconomic disadvantage across the life-course and oral health in older age: Findings from a longitudinal study of older British men. J Public Health. 40(4): e423-e430.

Raudenbush SW, Eschmann RD. 2015. Does schooling increase or reduce social inequality? Annu Rev Sociol. 41(1):443-470.

Schattner EL, Tsao T-F. 1981. Dentistry in the People's Republic of China. J Am Dent Assoc. 102(1):14-22.

Shen J, Wildman J, Steele J. 2013. Measuring and decomposing oral health inequalities in an UK population. Community Dent Oral Epidemiol. 41(6), 481-489.

Singh-Manoux A, Adler NE, Marmot MG. 2003. Subjective social status: its determinants and its association with measures of ill-health in the Whitehall II study. Soc Sci Med. 56, 1321-1333.

Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, Abbasi-Kangevari M, Abbastabar H, Abd-Allah F, Abdelalim A. 2020. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the global burden of disease study 2019. Lancet. 396(10258):1204-1222.

Weston R, Gore Jr PA. 2006. A brief guide to structural equation modeling. Couns Psychol. 34(5):719-751.

Wong SY, Mercer SW, Woo J, Leung J. 2008. The influence of multi- morbidity and self-reported socio-economic standing on the prevalence of depression in an elderly Hong Kong population. BMC Public Health, 8, 1-6.

Zeng Y, Poston DL, Vlosky DA, Gu D. 2008. Healthy longevity in china: Demographic, socioeconomic, and psychological dimensions. Beijing: Springer Science & Business Media.

Zhang X, Chen S. 2019. Association of childhood socioeconomic status with edentulism among Chinese in mid-late adulthood. BMC Oral Health. 19(1):1-11.

Zhang X, Dai S, Jiang X, Huang W, Zhou Q, Wang S. 2023. The pathways from disadvantaged socioeconomic status in childhood to edentulism in mid-to-late adulthood over the life-course. Int J Equity Health. 22(1):150.

Zhou X, Tang J, Tan J. 2013. The history of stomatology. Beijing: People's Medical Publishing House.